EARTH RETAINING SYSTEMS

(from *Highway Design Manual*)

1. Types and Uses

Earth retaining systems can be divided into five categories:

- State-designed systems which involve a Standard Plan;
- State-designed systems which require special design;
- Proprietary systems which have been preapproved by the Division of Structures (DOS) for listing in Special Provisions for specific projects;
- Proprietary systems which are awaiting DOS approval;
- Experimental systems.

(1) State-Designed Earth Retaining Systems with Standard Plans. Standard Plans are available for a variety of earth retaining systems (retaining walls). Loading conditions and foundation requirements are outlined in the Standard Plans. For sites with requirements that are not covered by the Standard Plans, a special design earth retaining system is required. To assure conformance with the Standard Plan requirements and, therefore, completion of the PS&E in a timely fashion, *design engineers should request a foundation investigation* for all locations at which a retaining wall is being considered. Retaining walls which have Standard Plans are as follows:

(a) Retaining Wall Types 1 and 2 (Concrete Cantilever). These walls have standard design heights up to 36 feet, but are most economical below 20 feet. Concrete cantilever walls accommodate traffic barriers, sound walls, and drainage facilities efficiently.

(b) Retaining Wall Types 3 and 4 (Concrete Counterfort). These walls may be used where minimum wall deflection is desired. When used in conjunction with concrete cantilever walls, there should be an offset in the plane of the wall faces to mask the difference in deflection between the two wall types. The cost of these walls is generally more than for concrete cantilever walls of similar height.

(c) Retaining Wall Type 5 (Concrete L-Type Cantilever). Although more costly than cantilever walls, these walls may be required where site restrictions do not allow for a footing projection beyond the face of the wall stem.

(d) Retaining Wall Type 6 (Concrete Masonry Walls). These walls may be used where the design height does not exceed 6 feet. These walls are generally less costly than all other standard design walls or gravity walls. Where traffic is adjacent to the top of the wall, guardrail should be set back as noted in the Standard Plans.

(e) Crib Walls. The following types are available:

- Concrete Crib Wall. This type of crib wall may be used for design heights up to 50 feet. Concrete crib walls are suited to coastal areas and higher elevations where salt air and deicing salts may limit the service life of other types of crib walls. Concrete crib walls may be closed face and, therefore, useful where impinging flow is a problem.

- Steel Crib Wall. This type of crib wall may be used for design heights up to 36 feet. Steel crib walls are light in weight; easily transported and installed; and, therefore, suited for relatively inaccessible installations and for emergency repairs.

- Timber Crib Wall. This type of crib wall may be used for design heights up to 22 feet. Timber crib walls have a rustic appearance which makes them suited to a rural environment. When all of the wood members are pressure preservative treated, the service life of timber crib walls is comparable to that of concrete or steel crib walls.

Timber and concrete crib walls constructed on horizontal alignments with curves or angle points require special details, particularly when the wall face is battered. Because crib wall faces can be climbed, they are not recommended for urban sites where they will be accessible to the public. The economical height for all crib walls is generally less than 30 feet.

(2) State-Designed Earth Retaining Systems which Require Special Designs. Some sites require a special design earth retaining system to accommodate existing and future ground contours, traffic, utilities or other constructed features, site geology, economy, or aesthetics.

Some special design earth retaining systems are as follows:

(a) Standard Plan Walls. The design loadings, heights, and types of walls in the Standard Plans cover frequent applications for earth retaining systems. However, special designs are necessary if the imposed loading exceeds that in the Standard Plans. Railroad live load; building surcharge; loads imposed by sign structures, electroliers, or sound walls are examples. Foundation conditions that require pile support for the wall necessitates a special design. Design is by DOS.

(b) Bulkheads. These systems are also referred to as cantilevered pile, sheet pile, tie-back, anchored pile, or soldier pile walls. These walls are most practical in cut sections and are best suited for situations where excavation for a retaining wall with a footing is impractical because of traffic, utilities, existing buildings or right of way restrictions. In embankment sections, a bulkhead wall is a practical solution for a roadway widening where design heights are less than 6 feet. They are also practical for slip-out corrections. Bulk heads can consist of either concrete, steel, or timber sheet piles, or concrete, steel or timber soldier piles either driven or placed in drilled holes and backfilled, with either concrete facing or lagging or timber lagging. Bulkhead walls can be either cantilevered or anchored with tie rod and deadman anchors, ground anchors,

or rock anchors. The method of support and anchorage depends on site conditions, design height, and loading imposed. The cost of these walls is variable depending on earth retaining requirements, site geology, aesthetic consideration, and site restraints. Design is by DOS.

(c) Concrete or Rock Gravity Walls. These walls are most economical at design heights below 4 feet. They are constructed at heights between 4 and 6 feet only for short lengths, and then only if considerable length of the shorter height is involved. These walls can be used in connection with a cantilever wall if long lengths of wall with design heights of less than 4 feet are required. A Type 50C concrete barrier, which can be found in the Standard Plans, can serve as a gravity retaining wall in locations where a differential in height of up to 3 feet exists between adjoining roadway grades. Design is by DOS.

(d) Soil Reinforcement Systems. Soil reinforcement systems are generally less costly than standard design walls or gravity walls when the wall height is over 12 feet. These systems offer the advantage of structural flexibility and can, therefore, tolerate greater differential settlement than conventional retaining walls.

Soil reinforcement systems require reinforcing elements in the soil mass. The reinforcement increases the soil strength and permits construction of a soil mass which acts like a gravity wall with a vertical, or near vertical, face. The reinforcing elements can be any material that will provide tensile strength and pullout resistance. Metallic reinforcement must be sized large enough to allow for corrosion losses throughout the life of the structure. Galvanizing metallic elements can extend the life of the structure. Facing elements for most systems are either concrete, light gauge steel, or treated wood. Selection of the facing element is governed by aesthetics and service life.

Special details are required when a reinforced soil wall must accommodate drainage structures or sound walls on piles within the reinforced backfill. Concrete safety shape barriers require a special design support slab when used at the top of soil reinforcing systems. These systems cannot be used where site excavation restrictions limit placement of the soil reinforcing elements.

Wall heights of soil reinforcement systems are controlled mainly by bearing capacity of the foundation materials. Wall heights in excess of 60 feet are feasible for some soil reinforcing systems where foundation conditions permit. Foundation investigations for soil reinforcement systems are similar to investigations for conventional retaining walls.

Soil reinforcement systems are designed by both the State and private firms. Those systems designed by private firms are termed “proprietary” and are listed in paragraphs (3) and (4). Some State-designed soil reinforcement systems that require special designs are as follows:

- Mechanically Stabilized Embankment (MSE). This soil reinforcement system was developed by TransLab. The license agreement with the Reinforced Earth Company expired August 29, 1989. The system utilizes welded wire mat reinforcement and precast concrete

face panels. MSE walls can be constructed using low strength on-site backfill material. Design is by DOS.

- Tire Anchor Timber (TAT) Walls. This soil reinforcement system was developed by Trans-Lab, and utilizes steel bars anchored by used tire sidewalls as reinforcement. These bars are attached to treated timber facing elements. TAT walls have a rustic appearance which makes them suited to a rural environment. Design is by TransLab.

- Salvaged Material Retaining Walls. This soil reinforcement system utilizes c-channel sections as soil reinforcement and galvanized metal beam guardrail, timber posts, or concrete panels as facing materials. Often the elements involved in this system can be salvaged from state rehabilitation projects. The District Material Manager should be consulted as to availability of salvaged materials. Design is by TransLab.

(3) Proprietary Earth Retaining Systems (Preapproved). These conventional retaining walls, cribwalls, and soil reinforcement systems are designed, manufactured, and marketed by a vendor. These systems are termed proprietary because most of these systems are patented. Preapproval status means that these systems will be listed in the Special Provisions of the project as an Alternative Earth Retaining System (AERS) when considered appropriate for a particular location. For a proprietary system to be given preapproval status, the vendor must submit standard plans and design calculations to DOS for their review and approval. Pre-approved proprietary earth retaining systems are as follows:

(a) Reinforced Earth (RE). This French, patented soil reinforcement system is marketed by the Reinforced Earth Company. Reinforced Earth utilizes steel strips as soil reinforcing elements and precast concrete face panels.

(b) Reinforced Soil Embankment (RSE). This patented soil reinforcement system is marketed by the Hilfiker Company. Like MSE walls, RSE walls utilize welded wire mat soil reinforcement and precast concrete face panels, and can be constructed using low strength on-site material.

(c) Welded Wire Walls. This patented soil reinforcement system is marketed by The Hilfiker Company. Welded Wire Walls are constructed using welded wire mat units which are both the soil reinforcement and the facing element.

(d) Retained Earth (VSL) Walls. This patented soil reinforcement system is marketed by the VSL Corporation. Retained Earth walls are constructed using welded wire mesh for the soil reinforcement and precast concrete face panels.

(e) Criblock Walls. This patented concrete cribwall system is marketed by Criblock Retaining Walls of America, Inc. and is compatible to the State-designed concrete cribwall.

It should be noted that this list includes only those systems which were preapproved by DOS at the time of this revision. New systems will be added to the list as they are submitted, evaluated, and approved.

(4) Proprietary Earth Retaining Systems (Pending). The systems in this category have been submitted by a vendor to DOS for evaluation. They will undergo thorough review and any necessary testing and, with the approval of DOS, they will be added to the list of preapproved proprietary earth retaining systems and can be listed in the Special Provisions under Alternative Earth Retaining Systems.

The proprietary systems awaiting DOS approval are as follows:

(a) Geogrid Walls. This patented soil reinforcement system is marketed by the Tensar Corporation. Geogrid walls utilize a high tensile strength plastic grid as the soil reinforcing element of the wall. The geogrid can be precast into concrete facing panels; attached to precast facing panels after wall construction; or, when conditions allow, the wall face can be battered to allow planting on the stable, sloping face of the wall.

(b) Gabion Walls. This system is marketed by Terra Aqua, Inc. Gabion walls utilize rock filled wire basketlike elements which act as a gravity wall. They can be used to stabilize slopes and to provide protection from scour and erosion. All metallic elements must be galvanized. This system is very labor intensive and requires close construction control.

(c) Eureka Wall. This system is marketed by The Hilfiker Company. Eureka Wall is a soil reinforcement system with welded wire mats for soil reinforcement and cast-in-place concrete facing.

(d) Piano Wall. This system is marketed by the Reinforced Earth Company. Piano Wall is a soil reinforcement system which uses full height precast concrete face panels with an integral safety shape traffic barrier.

(e) Stresswall. This system is marketed by Stresswall International, Inc. Stresswall is similar in design principle to a tieback wall and utilizes precast concrete supporting and facing elements.

(f) Netupsky Wall. This system is marketed by the Netupsky Engineering Company, Ltd. Netupsky wall functions as a cantilever retaining wall and utilize steel frames, concrete toe and heel elements and precast concrete face elements.

It should be noted that this list includes only those systems being evaluated by DOS at the time of this revision. New systems will be added to the list as they are submitted.

In most cases, proprietary systems will be listed in the Special Provisions for a project under Alternative Earth Retaining Systems. However, if a proprietary system is the only retaining system deemed appropriate for a project and, therefore, the only system contained in the project documents, the construction of that system must be designated experimental construction in accordance with existing contract agreements concerning sole source purchases.

(5) Experimental State-Designed Earth Retaining Systems. Every earth retaining system must undergo a thorough evaluation before becoming accepted for routine use. Newly introduced designs or untried combinations of proprietary and non-proprietary designs or products are, therefore, considered experimental. Evaluation of the system may take the form of either a Category 1 Experimental Construction Project which is administered by TransLab or DOS or a Category 2 Experimental Construction Project (Construction Evaluation) which is administered through the Office of Engineering Services, Value Engineering and Resource Conservation Branch and requires a minimum of paperwork. The evaluation process in both cases is federally funded. Once a system has been evaluated, the experimental status will be changed.

Some earth retaining systems which are considered experimental are as follows:

(a) Soil Nailing. This system utilizes metal bars or tubes as soil reinforcement. Soil nailing is a low cost in-situ soil reinforcement system. The nails, or soil reinforcement, are installed in the excavation cut by either driving or placing and grouting in a predrilled hole. The excavation face between the reinforcement is stabilized with either reinforced shotcrete or intermittent rigid face elements. This system does not require excavation of the backfill to place the reinforcement, and can be constructed from the top down. Soil nailing is most applicable for retaining excavations and for stabilizing slopes. Design is by TransLab or DOS.

(b) Fabric or Plastic Reinforced Walls. These systems utilize geotextiles or plastics as the soil reinforcing elements. The face of these walls can be left exposed if the soil reinforcing material has been treated to prevent decay from ultra-violet rays. Concrete panels, mortarless masonry, tar emulsion, or Gunite may be used as facing materials or the face may be seeded if a more aesthetic treatment is preferred. Design is by TransLab.

(c) Mortarless Gravity Walls. Each of these systems utilizes the friction and shear developed between facing units and the combined weight of the units to retain the backfill. Some of these systems have been used as erosion protection at abutments and on embankments. They can be used as an aesthetic treatment for facing fabric and plastic soil reinforced walls. All of these systems require a batter. Design is by TransLab.

It should be noted that this list includes only those systems which are being evaluated by TransLab at the time of this revision. New systems will be added to the list as they are considered.

2. Alternative Earth Retaining Systems (AERS)

The Alternative Earth Retaining Systems procedure encourages competitive bidding and potentially results in cost savings. Therefore, AERS should be implemented in preparing all project documents involving earth retaining systems.

DOS initiated the Alternative Earth Retaining Systems (AERS) procedure in 1982. Implementation of the procedure means that various earth retaining systems are presented in the contract bid package and are, therefore, able to be considered for use by a contractor. Under this procedure, a fully detailed State-designed earth retaining system will be provided for each location, and will be used as the basis for payment. Additional systems may be presented in the contract documents as alternatives to the fully detailed State design and can be considered for use at specified locations. The fully detailed State-designed earth retaining system, which is used as the basis for payment, may be either a Standard Plan system or a special design system. Additional (or alternative) systems may be State-designed systems, preapproved proprietary systems, an experimental system, or any combination thereof. The State-designed alternative systems, both Standard Plan walls and special design systems, will be fully detailed on the plans. The alternative systems, which are preapproved proprietary systems, will be listed in the Special Provisions as Alternative Earth Retaining Systems.

Implementation of the AERS process requires the involvement of the District Design Engineer, DOS, and the TransLab. The District Design Engineer should submit pertinent site information (site plans, typical sections, etc.) to both the TransLab and DOS for feasibility studies as early as possible in the project design stage.

Under the AERS procedure, parts of the PS&E package which pertain to the earth retaining systems will be prepared as follows:

- Project plans for the State-designed systems can be prepared by the District Design Engineer (Standard Plan systems), TransLab (special design soil reinforcement systems and experimental systems), or DOS (Standard Plan systems and special design systems).

- Preapproved proprietary systems will be listed in the Special Provisions.

- Specifications and Estimates for the fully detailed State-designed system, which will be used as the basis for payment, will be prepared by DOS.

The earth retaining systems under this procedure will be measured and paid for by the square foot area of the face of the earth retaining system which has been indicated to be the basis of payment. Should an Alternative Earth Retaining System be constructed, payment will be made based on the measurements of the State-designed system which was designated as basis of payment. The contract price paid per square foot is for all items of work involved and includes excavation, backfill, drainage system, reinforcing steel, concrete, soil reinforcement, and facing. Any barrier, fence, or railing involved is measured and paid for as separate items.

3. Cost Reduction Incentive Proposals (CRIP)

The contractor may submit a proposal for an earth retaining system under Section 5-1.14 of the Standard Specifications, Cost Reduction Incentive. The proposed system may modify or replace the earth retaining system permitted by the contract. This gives vendors of proprietary earth retaining systems a method for having their system used prior to having preapproval of a standard plan submittal for that system. CRIP submittals are administered by the Office of Highway Construction with review assistance provided by DOS and the Transportation Laboratory.

4. Aesthetic Consideration

The profile of the top of wall should be designed to be as pleasing as the site conditions permit. All changes in the slope at the top of cast-in-place concrete walls should be rounded with vertical curves at least 20 feet long. Small dips in the top of the wall should be eliminated. Sharp dips should be improved by using vertical curves, slopes, steps, or combinations thereof. Side slopes may be flattened or other adjustments made to provide a pleasing profile.

Where walls are highly visible, special surface treatment or provisions for landscaping should be considered. Aesthetic treatment of walls should be referred to DOS for study by the Transportation Architecture Branch.

Walls should not contain indentations or protrusions, up to 6 feet above ground, that may snag a vehicle.

When alternative wall types are provided on projects with more than one wall site, any restriction as to the combination of wall types should be specified in the Special Provisions.

5. Safety Railing, Fences, and Concrete Barriers

Cable railing should be installed for employee protection in areas where employees may work adjacent to vertical faces of retaining walls, wingwalls, abutments, etc. and where the vertical fall is 7½ feet or more. See Standard Plans for details of cable railing.

Special designs for safety railing may be considered where aesthetic values of the area warrant special treatment.

Concrete barriers may be mounted on top of retaining walls. Details for concrete barriers mounted on top of retaining walls Type 1 through 5 are shown in the Standard Plans. A special design traffic slab is required if a concrete barrier is to be used at the top of cribwalls and most special design earth retaining systems. DOS should be contacted for preparation of the plans involved in the special design.

Retaining walls joining right of way fences should be a minimum of 6 feet clear height.

6. Design Responsibility

DOS has primary responsibility for the structural design and preparation of the contract documents (PS&E) for earth retaining systems in the Standard Plans and for the special designs involving bulkheads, concrete and rock gravity walls, pile support systems, and Mechanically Stabilized Embankment. DOS prepares the Specifications and Engineer's estimate for contracts where the Alternative Earth Retaining Systems (AERS) procedure is used. DOS reviews and approves standard plan submittals for proprietary earth retaining systems submitted by vendors. DOS assists Office of Highway Construction in evaluating the Cost Reduction Incentive Proposals (CRIP) submitted by contractors.

Districts may prepare contract plans, specifications, and engineer's estimate for Standard Plan retaining walls provided the foundation conditions and site requirements permit their use. A foundation investigation is required for all earth retaining structures. Project plans, specifications, and estimates for Tire Anchored Timber walls, Salvaged Material walls, and Experimental walls will be prepared by the District with the assistance of the Transportation Laboratory (TransLab). Earth retaining systems can be included in the PS&E as either Highway or Structure items.

Requests for the special design of a retaining system should be submitted at least 6 months before the PS&E is due. At least 2 months is required to conduct a foundation investigation for a retaining structure. A site plan, index map, cross sections, vertical and horizontal alignment, and utility and drainage requirements should be sent along with the request.

TransLab has responsibility for making foundation recommendations for all earth retaining systems. They assist the District Design Engineer with preparation of contract documents for special designs of Tire Anchor Timber walls, Salvage Material walls, and experimental earth retaining systems.

Both TransLab and DOS have responsibility for making feasibility studies for Alternative Earth Retaining Systems. The District should submit project site information (site plans, typical sections, etc.) to both of them as early in the planning stages as possible so that determination of the most appropriate earth retaining systems to use can be made.

7. Guidelines for Plan Preparation

(1) Type Selection. Wall type selection should be based on considerations set forth in 3-1.0. Both State-designed earth retaining systems and proprietary earth retaining systems may meet the requirements for a project. Therefore, to promote competitive bidding which can result in cost savings, all appropriate earth retaining systems should be included in the contract documents.

(2) Foundation Investigations. A foundation investigation should be requested from the Transportation Laboratory for all sites involving an earth retaining system. All log of test boring sheets accompanying the foundation reports must be included with the contract plans.

The following guidelines should be used to prepare the contract plans for earth retaining systems which are found in the Standard Plans:

(a) Loads. All wall types selected must be capable of supporting the field surcharge conditions. The design surchrges can be found in the Standard Plans. Deviance from these loadings will require a special design.

(b) Footing Steps. For economy and ease of construction of wall Types 1 through 6, the following criteria should be used for layout of footing steps.

- Distance between steps should be in multiples of 8 feet.

- A minimum number of steps should be used even if a slightly higher wall is necessary. Small steps, less than 12 inches in height, should be avoided unless the distance between steps is 96 feet or more. The maximum height of steps should be held to 4 feet. If the footing thickness changes between steps, the bottom of footing elevation should be adjusted so that the top of footing remains at the same elevation.

(c) Sloping Footings. The following criteria should be used for layout of sloping footings.

- The maximum permissible slope for reinforced concrete retaining walls is 3%. Maximum footing slope for masonry walls is 2%.

- When sloping footings are used, form and joint lines are permitted to be perpendicular and parallel to the footing for ease of construction.

- In cases where vertical electroliers or fence posts are required on top of a wall, the form and joint lines must also be vertical. A sloping footing should not be used in this situation since efficiency of construction would be lost.

- Sloping footing grades should be constant for the entire length of the wall. Breaks in footing grade will complicate forming and result in loss of economy. If breaks in footing grade are necessary, a level-stepped footing should be used for the entire wall.

- When the top of wall profile of crib walls is constant for the entire length, the bottom of wall profile may be sloped to avoid steps in the top of wall. In this case, all steps to compensate for changes of wall height and original ground profile would be made in the bottom of wall. The maximum permissible slope is 6%. If vertical electroliers or fence posts are required on top of the wall, the crib wall should not be sloped. Sloping crib walls are permissible with guard railing with vertical posts.

(d) Wall Joints. General details for required wall joints on wall Types 1, 1A, 2, and 5 are shown on Standard Plan B0-3. Expansion joints, Bridge Detail 3-3, should be shown at maximum intervals of 96 feet. Shorter spaces should be in multiples of 8 feet. Expansion joints should not

be placed at an angle point in the wall alignment. When concrete barriers are used on top of retaining walls, the waterstop in the expansion joint must be extended 6 inches into the barrier. This detail should be shown or noted on the wall plans. Weakened plane joints, Bridge Detail 3-2, should be shown at nearly equal spaces between joints.

(e) Drainage. Gutters should be used behind walls in areas where it is necessary to carry off surface water or to prevent scour. Low points in wall vertical alignment or areas between return walls must be drained by downspouts passing through the walls. Standard Plan B3-9 shows typical drainage details. Special design of surface water drainage facilities may be necessary depending on the amount of surface water anticipated. Where ground water is likely to occur in any quantity, special provisions must be made to intercept the flow to prevent inundation of the backfill and unsightly continuous flow through weep holes.

(f) Quantities. When the AERS procedure is not implemented, wall quantities for each item of work are usually set up for payment. The quantities for concrete and reinforcing steel shown on the Standard Plan sheets do not include any portion of the wall stem above the gutter elevation or toe of slope intersection. Quantities for expansion joint waterstop, structure excavation, structure backfill, pervious backfill material, concrete barrier or railing, and gutter concrete must be tabulated also. Quantities should be tabulated on the plans for each wall.

The following guidelines should be used to prepare the contract plans for soil reinforcement systems:

(a) Leveling Slabs. Most soil reinforcement systems do not require extensive foundation preparation. It may be necessary, however, to design a concrete leveling slab on which to construct the face elements. A reinforced concrete slab will be required in areas prone to consolidation or frost disturbance.

- Steps in the leveling slab should be the same height as the height of the facing elements or thickness of the soil layer between the soil reinforcement.

- Distance between steps in the leveling slabs should be in increments equivalent to the length of individual facing elements.

- A minimum number of steps should be used even if a slightly higher wall is necessary.

(b) Drainage. Gutters should be used behind walls in areas where it is necessary to carry off surface water or to prevent scour. Low points in wall vertical alignment or areas between return walls must be drained by downspouts passing through the walls. Special design of surface water drainage facilities will be necessary and should be prepared by DOS. Where ground water is likely to occur in any quantity, special provisions must be made to intercept the flow to prevent inundation of the backfill.

(c) Quantities. When the AERS procedure is not implemented, quantities for each item of work are usually set up for payment. Bid items shall include, but not be limited to: excavation and backfill for the embedment depth, soil reinforcement, facing elements, and concrete for slab construction. Additional bid items for inclusion are any drainage system, pervious backfill, concrete barrier, railings, and concrete gutters. Quantities should be tabulated on the plans for each wall.

The following miscellaneous details are applicable to all earth retaining systems:

(a) Utilities. Provisions must be made to relocate or otherwise accommodate utilities conflicting with the retaining wall. A utility opening for a Type 1 wall is shown in the Standard Plans. Any other utility openings will require special design details and should be reviewed by DOS.

(b) Electroliers and Signs. Details for mounting electroliers and signs on earth retaining systems are designed by the DOS. Requests for preparation of details should be made at least 3 months in advance of PS&E. To accommodate the base plates for overhead signs, a local enlargement may affect the horizontal clearance to both the edge of pavement and the right of way line. The enlargement should be considered at the time of establishing the wall layout. For mounting details, furnish DOS with a complete cross-section of the roadway at the sign and the layout and profile of the earth retaining system.

(c) Fence and Railing Post Pockets. Post pocket details shown for cable railing in the Standard Plans may also be used for mounting chain link fence on top of regaining walls. Special details may be necessary to accommodate the reinforcement in soil reinforcement systems.

(d) Return Walls. Return walls should be considered for use on the ends of the walls to provide a finished appearance. Return walls are necessary when wall offsets are used or when the top of wall is stepped. Return walls for soil reinforcement systems will require special designs to accommodate the overlapping of reinforcing elements.

All special wall details such as sign bases, utility openings, drainage features, fences, and concrete barriers should be shown on the plan sheet of the wall concerned or included on a separate sheet with the wall plan sheets. As a minimum, these details should be cross-referenced on the wall sheets to the sheets on which they are shown.

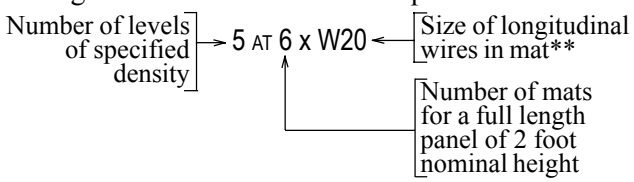
3-8 MECHANICALLY STABILIZED EMBANKMENT

WELDED WIRE MAT DENSITY PER FULL FACE PANEL - **ϕ (PHI) = 34°** BACKFILL MATERIAL

Loading Conditions	WALL HEIGHT						
	10'*	12'	14'	16'	18'	20'	22'
1	5 AT 6 x W11	6 AT 6 x W11	7 AT 6 x W11	2 AT 6 x W11 6 AT 4 x W11	9 AT 6 x W11	2 AT 6 x W11 8 AT 4 x W11	2 AT 6 x W11 9 AT 4 x W11
2	5 AT 6 x W11	6 AT 6 x W11	7 AT 6 x W11	1 AT 6 x W11 4 AT 4 x W11 3 AT 6 x W11	9 AT 6 x W11	1 AT 6 x W11 8 AT 4 x W11 1 AT 6 x W11	1 AT 6 x W11 9 AT 4 x W11 1 AT 6 x W11
3	5 AT 6 x W11	6 AT 6 x W11	7 AT 6 x W11	2 AT 6 x W11 6 AT 4 x W11	7 AT 6 x W11 2 AT 4 x W11	2 AT 6 x W11 8 AT 4 x W11	2 AT 6 x W11 9 AT 4 x W11
4A	5 AT 6 x W11	6 AT 6 x W11	7 AT 6 x W11	1 AT 6 x W11 7 AT 4 x W11	2 AT 6 x W11 7 AT 4 x W11	1 AT 6 x W11 9 AT 4 x W11	1 AT 6 x W11 10 AT 4 x W11
4B	5 AT 6 x W11	6 AT 6 x W11	7 AT 6 x W11	1 AT 6 x W11 7 AT 4 x W11	1 AT 6 x W11 8 AT 4 x W11	1 AT 6 x W11 8 AT 4 x W11 1 AT 6 x W11	1 AT 6 x W11 9 AT 4 x W11 1 AT 6 x W11
4C	5 AT 6 x W11	1 AT 6 x W11 5 AT 4 x W11	1 AT 6 x W11 5 AT 4 x W11 1 AT 6 x W11	1 AT 6 x W11 7 AT 4 x W11	1 AT 6 x W11 8 AT 4 x W11	1 AT 6 x W11 8 AT 4 x W11 1 AT 6 x W11	1 AT 6 x W11 8 AT 4 x W11 2 AT 6 x W11
4D	1 AT 6 x W11 3 AT 4 x W11 1 AT 6 x W11	1 AT 6 x W11 4 AT 4 x W11 1 AT 6 x W11	1 AT 6 x W11 3 AT 4 x W11 3 AT 6 x W11	1 AT 6 x W11 7 AT 4 x W11	1 AT 6 x W11 8 AT 4 x W11	1 AT 6 x W11 8 AT 4 x W11 1 AT 6 x W11	1 AT 6 x W11 8 AT 4 x W11 2 AT 6 x W11
4E	1 AT 6 x W11 4 AT 4 x W11	1 AT 6 x W11 5 AT 4 x W11	1 AT 6 x W11 6 AT 4 x W11	1 AT 6 x W11 7 AT 4 x W11	1 AT 6 x W11 6 AT 4 x W11 2 AT 6 x W11	1 AT 6 x W11 6 AT 4 x W11 3 AT 6 x W11	1 AT 6 x W11 6 AT 4 x W11 4 AT 6 x W11
5A, 5B, 5C & 5D	5 AT 6 x W11	6 AT 6 x W11	7 AT 6 x W11	2 AT 6 x W11 6 AT 4 x W11	9 AT 6 x W11	2 AT 6 x W11 6 AT 4 x W11l	2 AT 6 x W11 9 AT 4 x W11

* For wall heights less than 10', use 6 x W11 for each level of mats.

Legend for soil reinforcement specified:



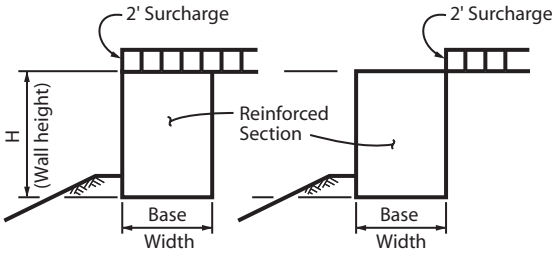
** W11 (Imperial) = MW70 (Metric)
W20 (Imperial) = MW130 (Metric)

WELDED WIRE MAT DENSITY PER FULL FACE PANEL - ϕ (PHI) = 34° BACKFILL MATERIAL

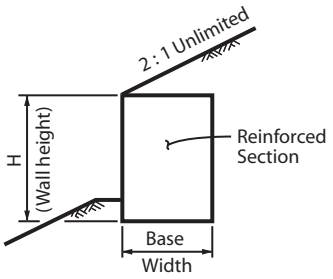
Loading Conditions	WALL HEIGHT						
	24'	26'	28'	30'	32'	34'	36'
1	3 AT 6 x W11 9 AT 4 x W11	2 AT 6 x W11 10 AT 4 x W11 1 AT 6 x W11	1 AT 6 x W11 11 AT 4 x W11 2 AT 6 x W11	1 AT 6 x W11 11 AT 4 x W11 3 AT 6 x W11	1 AT 6 x W11 12 AT 4 x W11 3 AT 6 x W11	1 AT 6 x W11 12 AT 4 x W11 4 AT 6 x W11	1 AT 6 x W11 12 AT 4 x W11 5 AT 6 x W11
2	1 AT 6 x W11 9 AT 4 x W11 2 AT 6 x W11	1 AT 6 x W11 9 AT 4 x W11 3 AT 6 x W11	1 AT 6 x W11I 9 AT 4 x W11 4 AT 6 x W11	1 AT 6 x W11 9 AT 4 x W11 4 AT 6 x W11 1 AT 4 x W20	1 AT 6 x W11 9 AT 4 x W11 4 AT 6 x W11 2 AT 4 x W20	1 AT 6 x W11 9 AT 4 x W11 4 AT 6 x W11 3 AT 4 x W20	1 AT 6 x W11 9 AT 4 x W11 4 AT 6 x W11 4 AT 4 x W20
3	3 AT 6 x W11 9 AT 4 x W11	2 AT 6 x W11 11 AT 4 x W11	1 AT 6 x W11 12 AT 4 x W11 1 AT 6 x W11	1 AT 6 x W11 12 AT 4 x W11 2 AT 6 x W11	1 AT 6 x W11 13 AT 4 x W11 2 AT 6 x W11	1 AT 6 x W11 13 AT 4 x W11 3 AT 6 x W11	1 AT 6 x W11 13 AT 4 x W11 4 AT 6 x W11
4A	1 AT 6 x W11 10 AT 4 x W11 1 AT 6 x W11	1 AT 6 x W11 10 AT 4 x W11 2 AT 6 x W11	1 AT 6 x W11 11 AT 4 x W11 2 AT 6 x W11	1 AT 6 x W11 11 AT 4 x W11 3 AT 6 x W11	1 AT 6 x W11 11 AT 4 x W11 4 AT 6 x W11	1 AT 6 x W11 11 AT 4 x W11 4 AT 6 x W11 1 AT 4 x W20	1 AT 6 x W11 11 AT 4 x W11 5 AT 6 x W11 1 AT 4 x W20
4B	1 AT 6 x W11 9 AT 4 x W11 2 AT 6 x W11	1 AT 6 x W11 9 AT 4 x W11 3 AT 6 x W11	1 AT 6 x W11 9 AT 4 x W11 4 AT 6 x W11	1 AT 6 x W11 10 AT 4 x W11 4 AT 6 x W11	1 AT 6 x W11 10 AT 4 x W11 4 AT 6 x W11 1AT4 x W20	1 AT 6 x W11 10 AT 4 x W11 4 AT 6 x W11 2 AT 4 x W20	1 AT 6 x W11 10 AT 4 x W11 4 AT 6 x W11 3 AT 4 x W20
4C	1 AT 6 x W11 8 AT 4 x W11 3 AT 6 x W11	1 AT 6 x W11 8 AT 4 x W11 4 AT 6 x W11	1 AT 6 x W11 9 AT 4 x W11 4 AT 6 x W11	1 AT 6 x W11 9 AT 4 x W11 4 AT 6 x W11 1 AT 4 x W20	1 AT 6 x W11 9 AT 4 x W11 4 AT 6 x W11 2 AT 4 x W20	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 3 AT 4 x W20	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 4 AT 4 x W20
4D	1 AT 6 x W11 8 AT 4 x W11 3 AT 6 x W11	1 AT 6 x W11 8 AT 4 x W11 3 AT 6 x W11 1 AT 4 x W20	1 AT 6 x W11 8 AT 4 x W11 4 AT 6 x W11 1 AT 4 x W20	1 AT 6 x W11 8 AT 4 x W11 4 AT 6 x W11 2 AT 4 x W20	1 AT 6 x W11 8 AT 4 x W11 4 AT 6 x W11 3 AT 4 x W20	1 AT 6 x W11 8 AT 4 x W11 4 AT 6 x W11 4 AT 4 x W20	1 AT 6 x W11 8 AT 4 x W11 4 AT 6 x W11 5 AT 4 x W20
4E	1 AT 6 x W11 5 AT 4 x W11 6 AT 6 x W11	1 AT 6 x W11 5 AT 4 x W11 5 AT 6 x W11 2 AT 4 x W20	1 AT 6 x W11 4 AT 4 x W11 6 AT 6 x W11 3 AT 4 x W20	1 AT 6 x W11 4 AT 4 x W11 6 AT 6 x W11 4 AT 4 x W20	1 AT 6 x W11 4 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20	1 AT 6 x W11 3 AT 4 x W11 6 AT 6 x W11 7 AT 4 x W20	1 AT 6 x W11 3 AT 4 x W11 6 AT 6 x W11 8 AT 4 x W20
5A, 5B, 5C & 5D	3 AT 6 x W11 9 AT 4 x W11	2 AT 6 x W11 10 AT 4 x W11 1 AT 6 x W11	1 AT 6 x W11 11 AT 4 x W11 2 AT 6 x W11	2 AT 6 x W11 10 AT 4 x W11 3 AT 6 x W11	1 AT 6 x W11 12 AT 4 x W11 3 AT 6 x W11	2 AT 6 x W11 11 AT 4 x W11 4 AT 6 x W11	1 AT 6 x W11 12 AT 4 x W11 4 AT 6 x W11 1 AT 4 x W20

WELDED WIRE MAT DENSITY PER FULL FACE PANEL - ϕ (PHI) = 34° BACKFILL MATERIAL

Loading Conditions	WALL HEIGHT						
	38'	40'	42'	44'	46'	48'	50'
1	1 AT 6 x W11 12 AT 4 x W11 5 AT 6 x W11 1 AT 4 x W20	1 AT 6 x W11 12 AT 4 x W11 5 AT 6 x W11 2 AT 4 x W20	1 AT 6 x W11 12 AT 4 x W11 6 AT 6 x W11 2 AT 4 x W20	1 AT 6 x W11 13 AT 4 x W11 5 AT 6 x W11 3 AT 4 x W20	1 AT 6 x W11 13 AT 4 x W11 5 AT 6 x W11 4 AT 4 x W20	1 AT 6 x W11 13 AT 4 x W11 5 AT 6 x W11 3 AT 4 x W20	1 AT 6 x W11 13 AT 4 x W11 6 AT 6 x W11 5 AT 4 x W20
2	1 AT 6 x W11 9 AT 4 x W11 5 AT 6 x W11 4 AT 4 x W20	1 AT 6 x W11 9 AT 4 x W11 5 AT 6 x W11 5 AT 4 x W20	1 AT 6 x W11 9 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20	1 AT 6 x W11 9 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20 1 AT 6 x W20	1 AT 6 x W11 9 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20 2 AT 6 x W20	1 AT 6 x W11 9 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20 3 AT 6 x W20	1 AT 6 x W11 9 AT 4 x W11 5 AT 6 x W11 7 AT 4 x W20 3 AT 6 x W20
3	1 AT 6 x W11 13 AT 4 x W11 5 AT 6 x W11	1 AT 6 x W11 13 AT 4 x W11 5 AT 6 x W11 1 AT 4 x W20	1 AT 6 x W11 13 AT 4 x W11 5 AT 6 x W11 2 AT 4 x W20	1 AT 6 x W11 13 AT 4 x W11 6 AT 6 x W11 2 AT 4 x W20	1 AT 6 x W11 13 AT 4 x W11 6 AT 6 x W11 3 AT 4 x W20	1 AT 6 x W11 14 AT 4 x W11 5 AT 6 x W11 4 AT 4 x W20	1 AT 6 x W11 14 AT 4 x W11 5 AT 6 x W11 5 AT 4 x W20
4A	1 AT 6 x W11 11 AT 4 x W11 5 AT 6 x W11 2 AT 4 x W20	1 AT 6 x W11 11 AT 4 x W11 5 AT 6 x W11 3 AT 4 x W20	1 AT 6 x W11 12 AT 4 x W11 5 AT 6 x W11 3 AT 4 x W20	1 AT 6 x W11 12 AT 4 x W11 5 AT 6 x W11 4 AT 4 x W20	1 AT 6 x W11 12 AT 4 x W11 5 AT 6 x W11 5 AT 4 x W20	1 AT 6 x W11 12 AT 4 x W11 6 AT 6 x W11 5 AT 4 x W20	1 AT 6 x W11 12 AT 4 x W11 6 AT 6 x W11 6 AT 4 x W20
4B	1 AT 6 x W11 10 AT 4 x W11 4 AT 6 x W11 4 AT 4 x W20	1 AT 6 x W11 10 AT 4 x W11 4 AT 6 x W11 5 AT 4 x W20	1 AT 6 x W11 10 AT 4 x W11 4 AT 6 x W11 6 AT 4 x W20	1 AT 6 x W11 10 AT 4 x W11 5 AT 6 x W11 6 AT4 x W20	1 AT 6 x W11 10 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20 1 AT 6 x W20	1 AT 6 x W11 10 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20 2 AT 6 x W20	1 AT 6 x W11 10 AT 4 x W11 5 AT 6 x W11 7 AT 4 x W20 2 AT 6 x W20
4C	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 5 AT 4 x W20	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 7 AT 4 x W20	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20 2 AT 6 x W20	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 7 AT 4 x W20 2 AT 6 x W20	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 7 AT 4 x W20 3 AT 6 x W20	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 7 AT 4 x W20 4 AT 6 x W20
4D	1 AT 6 x W11 8 AT 4 x W11 4 AT 6 x W11 6 AT 4 x W20	1 AT 6 x W11 8 AT 4 x W11 4 AT 6 x W11 6 AT 4 x W20 1 AT 6 x W20	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 5 AT 4 x W20 2 AT 6 x W20	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20 2 AT 6 x W20	1 AT 6 x W11 8 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20 3 AT 6 x W20	1 AT 6 x W11 7 AT 4 x W11 6 AT 6 x W11 6 AT 4 x W20 4 AT 6 x W20	1 AT 6 x W11 7 AT 4 x W11 6 AT 6 x W11 6 AT 4 x W20 5 AT 6 x W20
4E	1 AT 6 x W11 2 AT 4 x W11 6 AT 6 x W11 9 AT 4 x W20 1 AT 6 x W20	1 AT 6 x W11 2 AT 4 x W11 6 AT 6 x W11 9 AT 4 x W20 2 AT 6 x W20	8 AT 6 x W11 10 AT 4 x W20 3 AT 6 x W20	8 AT 6 x W11 9 AT 4 x W20 5 AT 6 x W20	7 AT 6 x W11 10 AT 4 x W20 6 AT 6 x W20	7 AT 6 x W11 10 AT 4 x W20 7 AT 6 x W20	6 AT 6 x W11 10 AT 4 x W20 9 AT 6 x W20
5A, 5B, 5C & 5D	1 AT 6 x W11 12 AT 4 x W11 5 AT 6 x W11 1 AT 4 x W20	1 AT 6 x W11 12 AT 4 x W11 5 AT 6 x W11 2 AT 4 x W20	1 AT 6 x W11 12 AT 4 x W11 5 AT 6 x W11 3 AT 4 x W20	1 AT 6 x W11 13 AT 4 x W11 5 AT 6 x W11 3 AT 4 x W20	1 AT 6 x W11 13 AT 4 x W11 5 AT 6 x W11 4 AT 4 x W20	1 AT 6 x W11 13 AT 4 x W11 5 AT 6 x W11 5 AT 4 x W20	1 AT 6 x W11 13 AT 4 x W11 5 AT 6 x W11 6 AT 4 x W20



LOADING CONDITION 1



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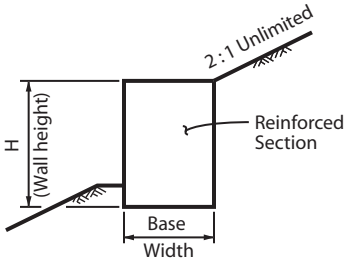
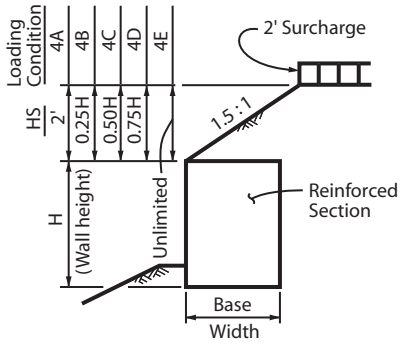
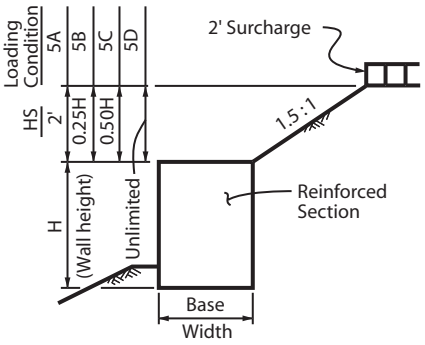


LOADING CONDITION 3



LOADING CONDITIONS 4A THRU 4E



LOADING CONDITIONS 5A THRU 5D

Notes:

1. Sequence of specified soil reinforcement for a given wall height and loading condition is from the top panel level to the bottom panel level.
2. Spacing of transverse wires of the welded wire mats shall be as follows:

   Mats for top panels - 12 inches
   Mats for the 3 levels of panels immediately below a top panel - 18 inches
   Mats for all remaining lower levels of panels - 24 inches
3. The density of soil reinforcement specified for the top level is to be used for all levels of mats in a top panel which has more than one level mats.
4. For a given wall height, which has a top panel with more than one level of soil reinforcement, reduce a corresponding number of lower levels of specified soil reinforcement which have the least specified density of soil reinforcement. If the least specified density of soil reinforcement has more than one spacing of transverse wires, reduce the level with the greatest spacing of transverse wires.
5. Example: Design wall height equals 26 feet. Actual height of tier panels under consideration equals 25'-0" to 25'-6". Loading condition 1 and $\phi = 34°$ backfill material:

Specified	2 AT 6 x W11	← Top panel - 2 levels at this density
Soil	10 AT 4 x W11	← Panel below top panel - 1 level at this density
Reinforcement	1 AT 6 x W11	← Reduce by 1 level at this density

FOUNDATION PRESSURE IN KIPS PER SQ. FT.
ϕ (PHI) = 34° BACKFILL

BASE WIDTH	LOADING CONDITION	WALL HEIGHT										
		4'	6'	8'	10'	12'	14'	16'	18'	20'	22'	24'
8'	1	0.8	1.0	1.4	1.8	2.3						
	2	0.8	1.1	1.5	2.0	2.7						
	3	0.5	0.8	1.1	1.4	1.9						
	4A	0.8	1.1	1.5	2.0	2.7						
	4B	0.8	1.1	1.5	2.1							
	4C	0.8	1.2	1.8								
	4D	0.8	1.3	1.9								
	4E											
	5A	0.5	0.8	1.1	1.5	2.0						
	5B	0.5	0.8	1.1	1.5	2.0						
	5C	0.5	0.8	1.1	1.5	2.0						
	5D	0.5	0.8	1.2	1.6	2.1						
10'	1		1.0	1.3	1.6	2.0	2.5					
	2		1.2	1.5	1.9	2.4	3.0					
	3		0.8	1.0	1.4	1.7	2.1					
	4A		1.1	1.4	1.8	2.3	2.8					
	4B		1.1	1.4	1.9	2.4	3.1					
	4C		1.2	1.6	2.1							
	4D		1.2	1.8	2.3							
	4E											
	5A		0.8	1.1	1.4	1.7	2.2					
	5B		0.8	1.1	1.4	1.7	2.2					
	5C		0.8	1.1	1.4	1.8	2.2					
	5D		0.8	1.1	1.4	1.8	2.3					
12'	1		1.0	1.3	1.6	1.9	2.3	2.7	3.2			
	2		1.2	1.5	1.9	2.3	2.8	3.4	4.0			
	3		0.8	1.0	1.3	1.6	2.0	2.4	2.8			
	4A		1.1	1.4	1.7	2.1	2.5	3.0	3.6			
	4B		1.1	1.4	1.8	2.2	2.7	3.3				
	4C		1.2	1.5	1.9	2.5	3.3					
	4D		1.2	1.6	2.2	2.8	3.4					
	4E											
	5A		0.8	1.0	1.3	1.6	2.0	2.4	2.9			
	5B		0.8	1.0	1.3	1.6	2.0	2.4	2.9			
	5C		0.8	1.0	1.3	1.6	2.0	2.4	2.9			
	5D		0.8	1.1	1.4	1.7	2.1	2.6	3.2			
14'	1			1.2	1.5	1.8	2.2	2.5	3.0	3.4		
	2			1.6	1.8	2.2	2.7	3.2	3.7	4.4		
	3			1.0	1.3	1.6	1.9	2.2	2.6	3.0		
	4A			1.4	1.7	2.0	2.4	2.8	3.2	3.8		
	4B			1.4	1.7	2.1	2.5	3.0	3.6	4.4		
	4C			1.5	1.9	2.3	2.9	3.7				
	4D			1.6	2.0	2.7	3.2	3.8				
	4E											
	5A			1.0	1.3	1.6	1.9	2.3	2.6	3.1		
	5B			1.0	1.3	1.6	1.9	2.3	2.7	3.1		
	5C			1.0	1.3	1.6	1.9	2.3	2.7	3.1		
	5D			1.1	1.4	1.7	2.0	2.4	2.9	3.4		

FOUNDATION PRESSURE IN KIPS PER SQ. FT.
ϕ (PHI) = 34° BACKFILL

BASE WIDTH	LOADING CONDITION	WALL HEIGHT												
		10'	12'	14'	16'	18'	20'	22'	24'	26'	28'	30'	32'	34'
16'	1	1.5	1.8	2.1	2.4	2.8	3.2	3.6	4.1					
	2	1.9	2.2	2.6	3.1	3.5	4.1	4.7	5.4					
	3	1.3	1.5	1.8	2.2	2.5	2.9	3.3	3.7					
	4A	1.7	2.0	2.3	2.7	3.1	3.5	4.0	4.5					
	4B	1.7	2.1	2.4	2.8	3.3	3.9	4.6						
	4C	1.8	2.2	2.7	3.3	4.0								
	4D	2.0	2.4	3.1	3.6	4.2								
	4E													
	5A	1.3	1.6	1.8	2.2	2.5	2.9	3.3	3.8					
	5B	1.3	1.6	1.8	2.2	2.5	2.9	3.3	3.8					
	5C	1.3	1.6	1.9	2.2	2.6	3.0	3.4	3.9					
	5D	1.4	1.6	2.0	2.3	2.7	3.1	3.6	4.2					
18'	1		1.8	2.1	2.4	2.7	3.1	3.4	3.9	4.3				
	2		2.2	2.6	3.0	3.4	3.9	4.4	5.0	5.7				
	3		1.5	1.8	2.1	2.4	2.8	3.1	3.5	4.0				
	4A		2.0	2.3	2.6	2.9	3.3	3.7	4.2	4.7				
	4B		2.0	2.4	2.8	3.2	3.6	4.2	4.8	5.6				
	4C		2.2	2.6	3.1	3.6	4.4							
	4D		2.4	2.8	3.5	4.0	4.6	5.4						
	4E													
	5A		1.5	1.8	2.1	2.4	2.8	3.2	3.6	4.0				
	5B		1.5	1.8	2.1	2.4	2.8	3.2	3.6	4.0				
	5C		1.5	1.8	2.1	2.5	2.8	3.2	3.6	4.1				
	5D		1.6	1.9	2.2	2.6	3.0	3.4	3.9	4.4				
20'	1			2.0	2.3	2.6	3.0	3.3	3.7	4.1	4.6	5.0		
	2			2.6	3.0	3.4	3.8	4.3	4.8	5.4	6.0	6.7		
	3			1.8	2.1	2.4	2.7	3.0	3.4	3.8	4.2	4.6		
	4A			2.2	2.5	2.9	3.2	3.6	4.0	4.4	4.9	5.4		
	4B			2.3	2.7	3.1	3.5	4.0	4.5	5.1	5.8			
	4C			2.6	3.0	3.4	4.0	4.7	5.6					
	4D			2.8	3.3	3.9	4.4	5.1	5.8					
	4E													
	5A			1.8	2.1	2.4	2.7	3.1	3.4	3.8	4.2	4.7		
	5B			1.8	2.1	2.4	2.7	3.1	3.4	3.8	4.3	4.8		
	5C			1.8	2.1	2.4	2.7	3.1	3.5	3.9	4.3	4.8		
	5D			1.9	2.2	2.5	2.9	3.3	3.7	4.2	4.7	5.2		
22'	1				2.3	2.6	2.9	3.2	3.6	4.0	4.4	4.8	5.2	5.8
	2				3.0	3.3	3.8	4.2	4.7	5.2	5.8	6.4	7.0	7.8
	3				2.1	2.3	2.6	3.0	3.3	3.7	4.0	4.4	4.9	5.4
	4A				2.5	2.8	3.1	3.5	3.8	4.2	4.7	5.1	5.6	6.2
	4B				2.7	3.0	3.4	3.8	4.3	4.8	5.4	6.1	6.8	
	4C				2.9	3.4	3.8	4.4	5.1	5.9				
	4D				3.2	3.7	4.3	4.9	5.5	6.2				
	4E													
	5A				2.1	2.3	2.7	3.0	3.3	3.7	4.1	4.5	4.9	5.4
	5B				2.1	2.4	2.7	3.0	3.3	3.7	4.1	4.5	5.0	5.5
	5C				2.1	2.4	2.7	3.0	3.4	3.7	4.1	4.6	5.0	5.6
	5D				2.2	2.5	2.8	3.2	3.6	4.0	4.4	4.9	5.5	6.1

FOUNDATION PRESSURE IN KIPS PER SQ. FT.
ϕ (PHI) = 34° BACKFILL

BASE WIDTH	LOADING CONDITION	WALL HEIGHT															
		18'	20'	22'	24'	26'	28'	30'	32'	34'	36'	38'	40'	42'	44'	46'	
24'	1	2.6	2.9	3.2	3.5	3.8	4.2	4.6	5.0	5.5	6.0						
	2	3.3	3.7	4.1	4.6	5.0	5.6	6.1	6.7	7.4	8.1						
	3	2.3	2.6	2.9	3.2	3.6	3.9	4.3	4.7	5.1	5.6						
	4A	2.8	3.1	3.4	3.8	4.1	4.5	4.9	5.4	5.8	6.4						
	4B	3.0	3.4	3.7	4.2	4.6	5.1	5.7	6.3	7.1							
	4C	3.3	3.7	4.2	4.8	5.4	6.2										
	4D	3.6	4.2	4.7	5.3	5.9	6.6	7.3									
	4E																
	5A	2.3	2.6	2.9	3.2	3.6	3.9	4.3	4.7	5.2	5.6						
	5B	2.3	2.6	2.9	3.2	3.6	4.0	4.4	4.8	5.2	5.7						
	5C	2.3	2.6	3.0	3.3	3.6	4.0	4.4	4.8	5.3	5.8						
	5D	2.5	2.8	3.1	3.4	3.8	4.2	4.7	5.2	5.7	6.3						
26'	1		2.8	3.1	3.4	3.8	4.1	4.5	4.8	5.3	5.7	6.2	6.7				
	2		3.7	4.1	4.5	5.0	5.4	5.9	6.5	7.1	7.7	8.4	9.1				
	3		2.6	2.9	3.2	3.5	3.8	4.2	4.6	5.0	5.4	5.8	6.3				
	4A		3.0	3.4	3.7	4.0	4.4	4.8	5.2	5.6	6.1	6.6	7.1				
	4B		3.3	3.7	4.1	4.5	5.0	5.5	6.0	6.6	7.3	8.1					
	4C		3.6	4.1	4.6	5.2	5.8	6.6									
	4D		4.0	4.6	5.2	5.7	6.3	7.0	7.7								
	4E																
	5A		2.6	2.9	3.2	3.5	3.8	4.2	4.6	5.0	5.4	5.9	6.4				
	5B		2.6	2.9	3.2	3.5	3.9	4.2	4.6	5.0	5.4	5.9	6.4				
	5C		2.6	2.9	3.2	3.6	3.9	4.3	4.7	5.1	5.5	6.0	6.5				
	5D		2.8	3.1	3.4	3.7	4.1	4.5	5.0	5.5	6.0	6.5	7.1				
28'	1			3.1	3.4	3.7	4.0	4.4	4.7	5.1	5.5	5.9	6.4	6.9			
	2			4.1	4.5	4.9	5.3	5.8	6.3	6.8	7.4	8.0	8.7	9.4			
	3			2.8	3.1	3.4	3.8	4.1	4.5	4.8	5.2	5.6	6.1	6.5			
	4A			3.3	3.6	4.0	4.3	4.6	5.0	5.4	5.8	6.3	6.8	7.3			
	4B			3.6	4.0	4.4	4.8	5.3	5.8	6.3	6.9	7.6	8.3	9.1			
	4C			4.0	4.5	5.0	5.5	6.2	6.9	7.9							
	4D			4.4	5.1	5.6	6.1	6.7	7.4	8.1							
	4E																
	5A			2.8	3.1	3.4	3.8	4.1	4.5	4.8	5.2	5.6	6.1	6.6			
	5B			2.8	3.2	3.5	3.8	4.1	4.5	4.9	5.3	5.7	6.1	6.6			
	5C			2.9	3.2	3.5	3.8	4.2	4.5	4.9	5.3	5.8	6.2	6.7			
	5D			3.0	3.4	3.7	4.0	4.4	4.8	5.3	5.7	6.2	6.8	7.3			
30'	1				3.4	3.7	4.0	4.3	4.6	5.0	5.4	5.8	6.2	6.6	7.1	7.6	
	2				4.4	4.8	5.3	5.7	6.2	6.7	7.2	7.8	8.4	9.0	9.7	10.5	
	3				3.1	3.4	3.7	4.0	4.4	4.7	5.1	5.5	5.9	6.3	6.7	7.2	
	4A				3.6	3.9	4.2	4.6	4.9	5.3	5.7	6.1	6.5	7.0	7.5	8.0	
	4B				4.0	4.3	4.7	5.2	5.6	6.0	6.6	7.2	7.8	8.5	9.3		
	4C				4.4	4.8	5.4	5.9	6.6	7.3	8.2						
	4D				4.9	5.5	6.0	6.6	7.2	7.8	8.5	9.3					
	4E																
	5A				3.1	3.4	3.7	4.0	4.4	4.7	5.1	5.5	5.9	6.3	6.8	7.3	
	5B				3.1	3.4	3.7	4.1	4.4	4.8	5.1	5.5	5.9	6.4	6.8	7.3	
	5C				3.1	3.4	3.8	4.1	4.4	4.8	5.2	5.6	6.0	6.5	6.9	7.4	
	5D				3.3	3.6	4.0	4.3	4.7	5.1	5.5	6.0	6.5	7.0	7.6	8.2	

FOUNDATION PRESSURE IN KIPS PER SQ. FT.
ϕ (PHI) = 34° BACKFILL

BASE WIDTH	LOADING CONDITION	WALL HEIGHT												
		26'	28'	30'	32'	34'	36'	38'	40'	42'	44'	46'	48'	50'
32'	1	3.6	3.9	4.2	4.6	4.9	5.2	5.6	6.0	6.4	6.8	7.3	7.8	
	2	4.8	5.2	5.6	6.1	6.6	7.1	7.6	8.2	8.7	9.4	10.1	10.8	
	3	3.4	3.7	4.0	4.3	4.6	5.0	5.4	5.7	6.1	6.6	7.0	7.4	
	4A	3.8	4.2	4.5	4.8	5.2	5.6	5.9	6.3	6.8	7.2	7.7	8.2	
	4B	4.3	4.7	5.1	5.5	5.9	6.4	6.9	7.5	8.1	8.8	9.5	10.4	
	4C	4.8	5.2	5.7	6.3	6.9	7.7	8.5						
	4D	5.3	6.0	6.4	7.0	7.6	8.2	8.9	9.7					
	4E													
	5A	3.4	3.7	4.0	4.3	4.6	5.0	5.4	5.7	6.1	6.6	7.0	7.5	
	5B	3.4	3.7	4.0	4.3	4.7	5.0	5.4	5.8	6.2	6.6	7.1	7.6	
	5C	3.4	3.7	4.0	4.4	4.7	5.1	5.5	5.9	6.3	6.7	7.2	7.7	
	5D	3.6	3.9	4.3	4.6	5.0	5.4	5.8	6.3	6.8	7.3	7.8	8.4	
34'	1		3.9	4.2	4.5	4.8	5.2	5.5	5.9	6.3	6.7	7.1	7.5	8.0
	2		5.2	5.6	6.0	6.5	6.9	7.4	8.0	8.5	9.1	9.7	10.4	11.1
	3		3.6	3.9	4.2	4.6	4.9	5.3	5.6	6.0	6.4	6.8	7.2	7.7
	4A		4.1	4.4	4.8	5.1	5.4	5.8	6.2	6.6	7.0	7.4	7.9	8.4
	4B		4.6	5.0	5.4	5.8	6.3	6.7	7.3	7.8	8.4	9.1	9.8	10.6
	4C		5.1	5.6	6.1	6.7	7.3	8.0	8.8					
	4D		5.7	6.4	6.9	7.4	8.0	8.6	9.3	10.1				
	4E													
	5A		3.6	3.9	4.2	4.6	4.9	5.2	5.6	6.0	6.4	6.8	7.2	7.7
	5B		3.6	4.0	4.3	4.6	4.9	5.3	5.7	6.0	6.4	6.9	7.3	7.8
	5C		3.7	4.0	4.3	4.6	5.0	5.4	5.7	6.1	6.5	7.0	7.4	7.9
	5D		3.9	4.2	4.5	4.9	5.3	5.7	6.1	6.6	7.0	7.5	8.1	8.6
36'	1			4.2	4.4	4.8	5.1	5.4	5.8	6.1	6.5	6.9	7.3	7.8
	2			5.6	6.0	6.4	6.8	7.3	7.8	8.3	8.9	9.5	10.1	10.7
	3			3.9	4.2	4.5	4.8	5.2	5.5	5.9	6.3	6.6	7.1	7.5
	4A			4.4	4.7	5.0	5.4	5.7	6.1	6.4	6.8	7.3	7.7	8.1
	4B			4.9	5.3	5.7	6.1	6.6	7.1	7.6	8.1	8.7	9.3	10.0
	4C			5.5	6.0	6.5	7.1	7.7	8.4	9.2	10.1			
	4D			6.2	6.8	7.3	7.8	8.4	9.1	9.7	10.5	11.3		
	4E													
	5A			3.9	4.2	4.5	4.8	5.2	5.5	5.9	6.2	6.6	7.0	7.5
	5B			3.9	4.2	4.5	4.9	5.2	5.6	5.9	6.3	6.7	7.1	7.6
	5C			3.9	4.3	4.6	4.9	5.3	5.6	6.0	6.4	6.8	7.2	7.7
	5D			4.2	4.5	4.8	5.2	5.6	6.0	6.4	6.8	7.3	7.8	8.3
38'	1				4.4	4.7	5.0	5.4	5.7	6.0	6.4	6.8	7.2	7.6
	2				5.9	6.4	6.8	7.2	7.7	8.2	8.7	9.2	9.8	10.4
	3				4.2	4.5	4.8	5.1	5.4	5.8	6.2	6.5	6.9	7.3
	4A				4.7	5.0	5.3	5.6	6.0	6.3	6.7	7.1	7.5.	7.9
	4B				5.2	5.6	6.1	6.5	6.9	7.4	7.9	8.4	9.0	9.6
	4C				5.9	6.4	6.9	7.4	8.1	8.8	9.5	10.4		
	4D				6.6	7.2	7.7	8.3	8.9	9.5	10.2	10.9	11.6	
	4E													
	5A				4.2	4.5	4.8	5.1	5.4	5.8	6.1	6.5	6.9	7.3
	5B				4.2	4.5	4.8	5.1	5.5	5.8	6.2	6.6	7.0	7.4
	5C				4.2	4.5	4.8	5.2	5.5	5.9	6.3	6.6	7.1	7.5
	5D				4.5	4.8	5.1	5.4	5.8	6.2	6.7	7.1	7.6	8.1

FOUNDATION PRESSURE IN KIPS PER SQ. FT.
ϕ (PHI) = 34° BACKFILL

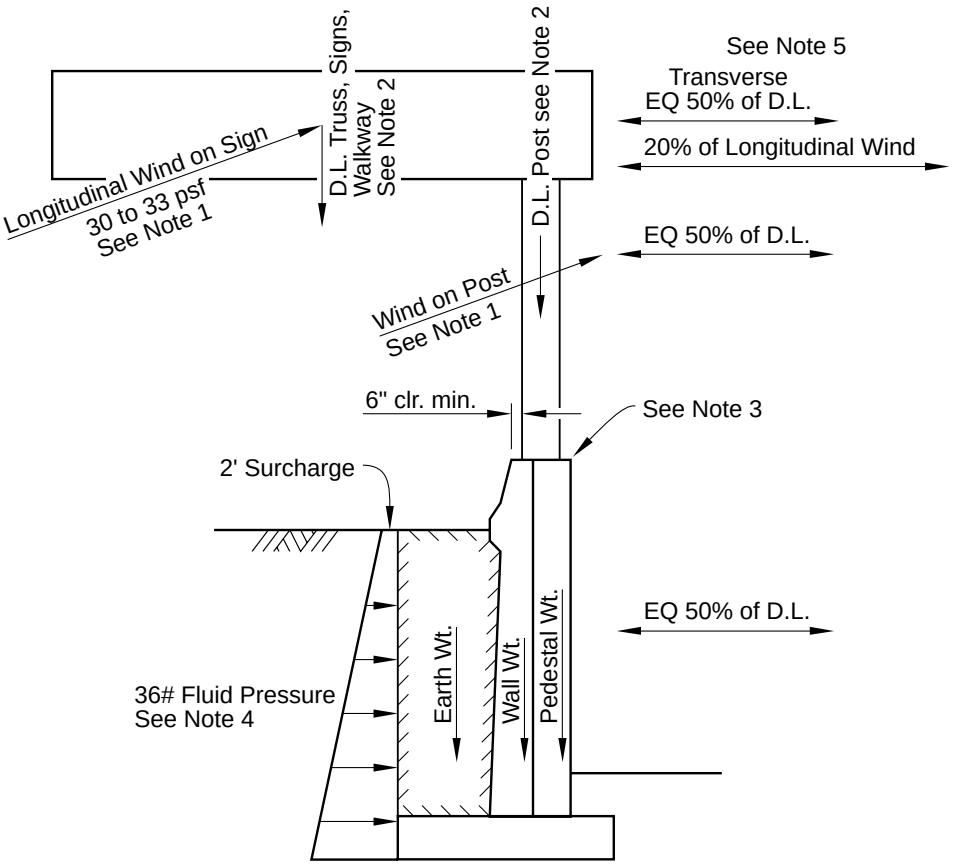
BASE WIDTH	LOADING CONDITION	WALL HEIGHT								
		34'	36'	38'	40'	42'	44'	46'	48'	50'
40'	1	4.7	5.0	5.3	5.6	6.0	6.3	6.7	7.0	7.4
	2	6.3	6.7	7.2	7.6	8.1	8.6	9.1	9.6	10.2
	3	4.4	4.7	5.1	5.4	5.7	6.1	6.4	6.8	7.2
	4A	4.9	5.2	5.6	5.9	6.2	6.6	7.0	7.4	7.8
	4B	5.6	6.0	6.4	6.8	7.2	7.7	8.2	8.8	9.3
	4C	6.2	6.7	7.2	7.8	8.4	9.1	9.9	10.8	
	4D	7.1	7.6	8.1	8.7	9.3	9.9	10.6	11.3	12.0
	4E									
	5A	4.4	4.7	5.0	5.4	5.7	6.0	6.4	6.8	7.1
	5B	4.4	4.8	5.1	5.4	5.7	6.1	6.4	6.8	7.2
	5C	4.5	4.8	5.1	5.5	5.8	6.2	6.5	6.9	7.3
	5D	4.8	5.1	5.4	5.7	6.1	6.5	7.0	7.4	7.8
42'	2		6.7	7.1	7.6	8.0	8.5	9.0	9.5	10.0
	4C		6.6	7.1	7.6	8.2	8.8	9.5	10.2	11.1
	4D		7.5	8.0	8.6	9.1	9.7	10.3	11.0	11.7
44'	2			7.1	7.5	7.9	8.4	8.8	9.3	9.8
	4C			7.0	7.5	8.0	8.6	9.2	9.9	10.6
	4D			7.9	8.5	9.0	9.5	10.1	10.8	11.4
46'	2				7.4	7.9	8.3	8.8	9.2	9.7
	4C				7.4	7.9	8.4	9.0	9.6	10.2
	4D				8.4	8.9	9.4	10.0	10.6	11.2

FOUNDATION PRESSURE IN KIPS PER SQ. FT. - LOADING CONDITION 4E
ϕ (PHI) = 34° BACKFILL

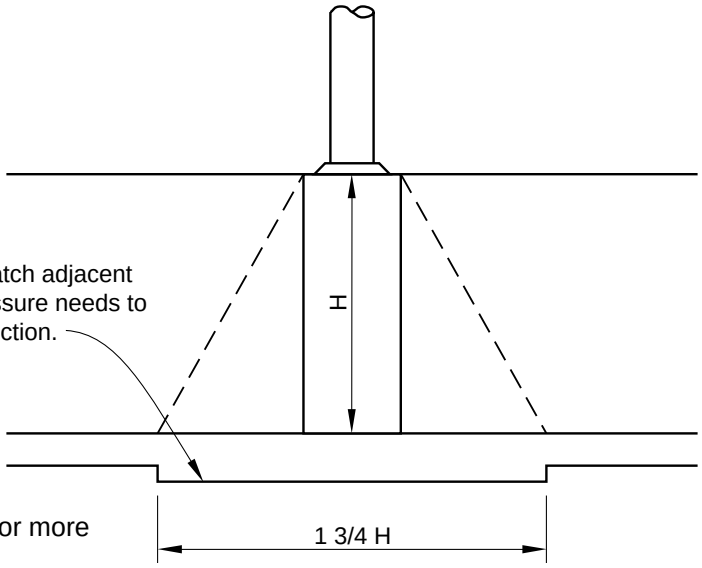
BASE WIDTH	WALL HEIGHT														
	4'	6'	8'	10'	12'	14'	16'	18'	20'	22'	24'	26'	28'	30'	32'
8'	1.1														
10'	1.2	1.5													
12'	1.2	1.6	1.9												
14'	1.3	1.7	2.0												
16'	1.4	1.8	2.1	2.5											
18'	1.5	1.9	2.2	2.6	2.9										
20'		2.0	2.3	2.6	3.0										
22'		2.1	2.4	2.7	3.1	3.4									
24'			2.5	2.8	3.2	3.5	3.9								
26'			2.6	2.9	3.2	3.6	4.0								
28'				3.0	3.3	3.7	4.0	4.4							
30'				3.1	3.4	3.8	4.1	4.5	4.9						
32'					3.5	3.9	4.2	4.6	4.9						
34					3.6	4.0	4.3	4.7	5.0	5.4					
36'						4.1	4.4	4.7	5.1	5.4	5.8				
38'						4.2	4.5	4.8	5.2	5.5	5.9				
40'							4.6	4.9	5.3	5.6	6.0	6.3			
42'							4.7	5.0	5.4	5.7	6.1	6.4	6.8		
44'								5.1	5.4	5.8	6.2	6.5	6.9		
46'								5.2	5.5	5.9	6.2	6.6	7.0	7.3	
48'									5.6	6.0	6.3	6.7	7.0	7.4	7.8
50'									5.7	6.1	6.4	6.8	7.1	7.5	7.8

BASE WIDTH	WALL HEIGHT														
	22'	24'	26'	28'	30'	32'	34'	36'	38'	40'	42'	44'	46'	48'	50'
52'	6.2	6.5	6.8	7.2	7.6	7.9	8.3								
54'	6.2	6.6	6.9	7.3	7.6	8.0	8.4	8.8							
56'		6.7	7.0	7.4	7.7	8.1	8.4	8.8							
58'		6.8	7.1	7.5	7.8	8.2	8.5	8.9	9.2						
60'			7.2	7.6	7.9	8.3	8.6	9.0	9.3	9.7					
62'			7.3	7.6	8.0	8.4	8.7	9.1	9.4	9.8					
64'				7.7	8.1	8.4	8.8	9.1	9.5	9.8	10.2				
66'				7.8	8.2	8.5	8.9	9.2	9.6	9.9	10.3	10.7			
68'					8.3	8.6	9.0	9.3	9.7	10.0	10.4	10.7			
70'					8.4	8.7	9.1	9.4	9.8	10.1	10.5	10.8	11.2		
72'						8.8	9.1	9.5	9.8	10.2	10.6	10.9	11.3	11.7	
74'						8.9	9.2	9.6	9.9	10.3	10.6	11.0	11.4	11.7	
76'							9.3	9.7	10.0	10.4	10.7	11.1	11.4	11.8	12.2
78'							9.4	9.8	10.1	10.4	10.8	11.2	11.5	11.9	12.2
80'								9.8	10.2	10.5	10.9	11.2	11.6	12.0	12.3

FORCES: Cantilever Sign Truss on Retaining Wall



Earthquake force of 50% should be applied to steel superstructure and retaining wall but not to earth weight.



Thicken and widen foundation to match adjacent soil pressures. If allowable soil pressure needs to be increased consult the geology section.

Overturning Safety Factor = 1.5 or more

FORCES: Cantilever Sign Truss on Retaining Wall

Note 1. Wind load on signs for 80 MPH design varies from 30 to 33 psf. Vertical supports are designed for the effects of wind from any direction by applying a combination of normal and transverse wind loads acting simultaneously. See AASHTO – "Standard Specification for Structural Supports for Highway Signs, Luminaires, and Traffic Signals," Section 1.2.5.

Note 2. Dead loads of trusses, walkways, and sign panels are given on Sign Reference Sheet No. 9.*

Note 3. Sign pedestal plan dimensions can be found on Standard Plan S13-10, page 153, *1988 Standard Plans*. If post type is not known and sign panel dimensions are available see Sheet 7 of Sign Reference Sheets.*

Note 4. Fluid pressure formula and tables are shown in *Bridge Design Aids*, 3-4.

Note 5. Do not combine wind and earthquake forces. Use combinations shown on Memo to Designers 22-1, page 3, Working Stress Design.

Sign foundation designs may be designed by the service load method using design allowables shown on Standard Plan B3-8, Retaining Wall Details (page 114, *1988 Standard Plans*).

*For Sign Reference Sheets see the Sign and Signal Supports Specialists.